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(12) # EUROPEAN PATENT SPECIFICATION

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(54) **Position sensing apparatus.**

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Description

Background of the Invention

This invention relates to position sensing apparatus. British Patent No. 1,551,218 describes apparatus for sensing the position of an object, comprising a first member for holding a stylus whereby to engage the object, a second member defining a support for the stylus, three units each connected to the respective members in position therebetween, the units having respective mutually perpendicular axes, and each unit comprising structure which is rigid against torsion but which is flexible in the sense permitting relative translation of the members in one direction transverse to the axis of the unit. The arrangement is such that one of the units is connected to the other two in position therebetween so that the units may be regarded as being connected "in series." Similar apparatus is shown in FR—A—2 304 891, US—A—3 990 153 and CH—A—549 438.

The known apparatus has the advantage of compact construction, but the serial connection of the units has the disadvantage of placing disuniform load on the respective units. Also, the units of the known apparatus each comprise two parts constrained for relative translation by a pair of parallel leaf springs connected to the parts in position therebetween. Such a connection can result in slight relative tilting of the members during a relative displacement thereof. Further, the arrangement of the units in said box-like construction can result in structure which is relatively complex and can be difficult to produce. It is an object of this invention to overcome at least one of these disadvantages.

Brief Description of the Invention

The invention claimed herein overcomes at least one of the above disadvantages by provisions including that each unit is connected between the respective members independently of the other units so that the units may be said to be connected "in parallel" between said members.

Thereby, compared to the known construction, the load exerted on the units in operation is more likely to be uniform, relative tilting of said members is less likely and/or the possibility of simpler construction is increased.

Description of Preferred Examples

Fig. 1 is a part sectional elevation of apparatus according to a first example,

Fig. 2 is a section on the line 2'—2' in Fig. 1,

Fig. 3 is a sectional elevation of a probe according to the second example, and

Fig. 4 is a sectional elevation of a probe according to a third example.

Referring to Figs. 1, 2, a probe generally denoted 1, comprises a first member or stylus holder 10 connected to a second member or support 12 by three units 20,30,40, arranged with reference to three mutually perpendicular directions A,B,C. The unit 20 comprises an arm 21 extending in the direction of an axis A1 lying in the direction A. The arm 21 is connected at one end thereof to the member 12 by a resilient pivot 22 having a pivot axis 23 lying in the direction B. The opposite or free end of the arm is connected to the moveable member 10 by a pair of parallel links 24 extending in the direction C and being spaced apart in the direction B. Each link 24 is connected at its ends to the adjacent portion of the member 10 and of the arm 21 by a resilient pivot 25. The pivots 25 allow universal pivotal or flexural motion of the links 24 relative to the member 10 and the arm 21. The pivot 22 comprises two relatively flexural elements one of which is fixedly connected to the member 12 and defines one end of the unit 20. The two pivots 25, situated at the ends of the two links 24 and adjacent to the member 10, each comprise two relatively flexural elements one of which is fixedly connected to the member 10. The elements of the pivots 25 thus connected to the member 10 define another end of the unit 20. Thus the unit 20 has two ends fixedly connected to the members 10 and 12, respectively. The units 30,40 each have two ends fixedly connected to the members 10 and 12, respectively, in the same way as the unit 20.

The units 30,40 have corresponding arms 31,41 extending in the direction of axes B1,C1 and having pivots 32,42 on axes 33,43. The free ends of the arms 31,41 are connected to the member 10 by respective pairs of links 34,44 extending in the directions A,B and having resilient pivots 35,45. Thus the units 20,30,40 constitute parallel connections between the members 10,12.

The arm 21 is dimensioned to be torsionally stiff about the axis A1 and the links 24 are of course stiff in the direction of their length. As a result the arm 21 and links 24 cooperate to constrain the member 10 against rotation relative to the member 12 about the axis A1. However the pivots 22,25,32,35,42,45 permit parallel movement of the member 10 relative to the member 12 in the directions A,B,C.

The arms 31,41 correspondingly constrain the member 10 against rotation about axes B1,C1 (which are parallel to the directions B,C respectively) and the pivots 22,25,32,35,42,45 permit movement of the member 10 in the directions A,B,C. Thus the three units 20,30,40 cooperate to constrain the member 10 against any rotation relative to the member 12 while permitting parallel motion relative to the member 12.

The arms 21,31,41 and links 24,34,44 are made of spring steel and the pivots 22,25,32,35,42,45 which are formed by weakened portions of the arms and the links, constitute springs which bias the member 10 into a rest position relative to the member 12. The member 10 is displaceable from the rest position in opposition to the spring force of the pivots 22,25,32,35,42,45 and the latter force returns the member 10 to the rest position when the displacing force ceases. Said displacement is sensed by inductive transducers 56,57,58

arranged between the member 12 and the respective arms 21,31,41.

It will be seen that the member 10 is generally cube-shaped and that, in each of the units 20,30,40 the arm 21,31 or 41 extends along one side of the cube while the corresponding link 24,34 or 44 extends at right angles to the arm along another side of the cube. This provides for a compact construction of the probe.

The member 12 comprises a housing 49 surrounding the member 10 and the units 20,30,40, and further comprises a spigot 50 for being secured to the head 55 of a coordinate measuring machine. The member 10 comprises a stylus socket 51 extending from the housing 49 through an opening 60 thereof, and further comprises a stylus 52 releasably connected to the socket, and having a spherical end 53. It will be clear that the stylus 53 is itself in a rest position when the member 10 is at its rest position.

A measuring operation to be carried out by the machine involves moving the head 55 relative to a workpiece 54 to bring the end 53 into engagement therewith, and to sense the consequent displacement of the member 10 from the rest position by means of the transducers 56,57,58. The measuring operation may involve halting the head during a said displacement in a known position relative to a machine datum and determining the magnitude of the displacement, i.e. the output of the transducers 56,57,58, when the head is halted. Alternatively, the measuring operation may involve outputting a pulse signal when a given magnitude of displacement is reached and to identify the position of the head at the instant of the pulse signal, the latter signal also being used to halt the head to avoid damage to the probe. These aspects of measuring are well understood *per se* and need not be further described.

The principal directions of measurement of the machine are defined by axes X,Y,Z.

In the example shown in Figs. 1,2 the directions A,B,C are defined by lines intersecting, and forming equal angles with, the axis Z which is a common axis for the spigot 50 and the stylus 52. In use the position of the probe is usually such that the axis Z is vertical. The arrangement has the advantage that the three units 20,30,40 are affected equally by gravity and by displacing forces transverse to the axis Z. However, inasmuch as the directions A,B,C are not parallel to the axes X,Y,Z, the output of the transducers has to be calibrated to allow for the angles of the directions A,B,C. Such calibration is only necessary if the measuring operation is such that the actual magnitude of the displacement has to be measured (as distinct from merely generating a said pulse signal).

As mentioned, the probe I has units 20,30,40 aligned with directions A,B,C each lying at an angle to the coordinate axes X,Y,Z of the machine. Distinct from this Fig. 3 shows a probe II in which the directions A,B,C are coincident with the axes X,Y,Z. Otherwise the probe II is the same as the probe I, like parts are given like reference numerals and apart from the angular relationship of the axes A,B,C and X,Y,Z, the description of the probe I applies equally to the probe II. One minor difference is that in Fig. 3 the transducers 56,57,58 are arranged between the member 10 and the housing 49 and as a consequence of the angular position of the units 10,20,30, the socket 51 is taken through a hole 61 in the arm 31.

Referring to Fig. 4, there is shown a probe III comprising a cube-shaped moveable member 110 connected to a fixed member 112 by three support units or bellows 120,130,140 having mutually perpendicular axes A1,B1,C1. The three bellows are arranged respectively between three adjacent sides of the member 110 and the interior of a housing 149 which is part of the member 112. The ends of each bellows is secured to the member 112 and the housing 149 e.g. by adhesive. Each bellows is made of a material, e.g. a suitable steel, which is resilient in bending but relatively rigid in shear so that the bellows is deflectable from its free position in any linear or angular sense except torsionally about its axis. Therefore the bellows cooperate to constrain the member 110 against rotation relative to the member 112 while allowing three-dimensional parallel motion of the member 110. The member 112 is provided with a spigot 150 for being secured to the head 155 of a coordinate measuring machine. The member 110 comprises a stylus socket 151 and a stylus 152 having a spherical end 153 for engagement with a workpiece 154 in the course of a measuring operation. Conveniently, the axes A1,B1,C1 intersect on an axis Z being the common axis of the spigot 150 and socket 151. However, the bellows can be arranged for the axes A1,B1,C1 to lie at equal angles to the axis Z substantially a shown with reference to the probe I. The member 110 is biased into a given three-dimensional rest position relative to the member 112 by the bias of the three resilient bellows towards their free position. Displacement of the member 110 from its zero position, i.e. by engagement of the stylus with the workpiece, is sensed by three transducers being proximity sensors 156,157,158 secured to the member 112 at the sides thereof opposite the respective bellows. The resilience of the bellows causes the member 110 to return to its rest position when the displacing force ceases. The housing 149 may be filled with a liquid 162 supporting the member 110 in a state of buoyancy thereby reducing or removing any load applied by the member 110 to the bellows due to gravity.

The housing 149 has a portion 163 defining an opening 160. The bellows 120 is connected between the member 112 and the portion 163, and the stylus extends to the exterior of the housing 149 through the bellows 120 and the hole 160. Thus the bellows 120 serves to seal the housing 149 at the opening 160.

Claims

1. Apparatus for sensing the position of an object (54;154), comprising:—

a) a first member (10;110) for holiding a stylus (52;152) whereby to engage the object (54;154),

b) a second member (12;112) defining a support for the stylus,

c) three units (20,30,40;120,130,140) mounted between the respective members(10,12;110,112),

d) the units (20,30,40;120,130,140) having respective mutually perpendicular axes (A1,B1,C1),

e) each unit (e.g. 20;120) comprising structure (21;120) which is rigid against torsion about the axis (A1) of the unit, and structure (22;120) which is flexible in the sense permitting relative translation of the members (10,12;110,112) in one direction (C) transverse to the axis (A1) of the unit (20;120), characterised in that

f) each unit (e.g. 20;120) is connected to both the members (10,12;110,112) independently of the other units (30,40;130,140), and

g) each unit (e.g. 20;120) comprises structure (24;120) which is flexible in the sense permitting relative translation of the members (10,12;110,112) in two other directions (A,B) each perpendicular to said one direction (C).

2. Apparatus according to claim 1 wherein the structure (24) which is flexible in the sense permitting relative translation of the members (10,12;110,112) in said other two directions (A,B;A,B) comprises pivot means (25) arranged between said rigid structure (21) and at least one of said members (10, 12).

3. Apparatus according to claim 1, wherein each said unit (e.g. 20) comprises an arm (21) secured at one end to one of said members (12), a pair of parallel links (24) connected between the other end of the arm (21) and the other one of said members (10), the arm (21) being rigid in torsion about the axis (A1) of the unit (20), first pivot means (22) permitting angular movement of the arm (21) relative to said one member (12) about a pivot axis (23) perpendicular to the axis (A1) of the unit (20), the links (24) extending in a direction (C) perpendicular to both the direction (A) of the axis (A1) of the unit (20) and the direction (B) of said pivot axis, the links (24) being spaced apart in the direction (B) of said pivot axis (23), and second pivot means (25) permitting universal angular movement of each said link (24) relative to said other member (10) and relative to the arm (21).

4. Apparatus according to claim 1, wherein each said unit (120, 130, 140) comprises one torsionally rigid but otherwise flexible bellows connected between the moveable and fixed members (110, 112).

5. Apparatus according to claim 1 including bias means (162) adapted to bias said members (10, 12) into a rest position, relative to one another.

6. Apparatus according to claim 1, wherein one of said members (120) comprises a housing (149), said other member (110) is situated within the housing (149), and a liquid (162) is provided within the housing (149) to support said other member (110) by virtue of the buoyancy of the liquid.

7. Apparatus according to claim 4, wherein one of said members (112) comprises a housing (149), said other of said members (110) is situated within the housing (149), the stylus (151, 152) projects from within the housing (149) thorugh a portion defining an opening (160) therein, and one of said bellows (130) is connected in a position between said other member (110) and said portion and so as to surround the stylus (151, 152) insofar as the latter extends within the housing (149).

Patentansprüche

1. Vorrichtung zum Erfassen der Position eines Gegenstands (54; 154) mit

a) einem ersten Glied (10; 110) zum Halten eines Griffels (52; 152), um dadurch mit dem Gegenstand (54; 154) in Eingriff zu gelangen,

b) einem zweiten Glied (12; 112), das einen Träger für den Griffel bestimmt,

c) drei Einheiten (20, 30, 40; 120 130, 140), die zwischen den entsprechenden Gliedern (10, 12; 110, 112) befestigt sind,

d) wobei die Einheiten (20, 30, 40; 120, 130, 140) entsprechende, gegenseitig senkrechte Achsen (A1, B1, C1) aufweisen,

e) wobei jede Einheit (z.B. 20; 120) einen Aufbau (21; 120) umfaßt, der gegenüber einer Verdrehung um die Achse (A1) der Einheit starr ist, und einen Aufbau (22; 120), der in dem Sinn flexibel ist, daß er eine Relativverschiebung der Glieder (10, 12; 110, 112) in einer Richtung (C) quer zur Achse (A1) der Einheit (20; 120) erlaubt, dadurch gekennzeichnet, daß

f) jede Einheit (z.B. 20; 120) mit beiden Gliedern (10, 12; 110, 112) unabhänging von den anderen Einheiten (30, 40; 120, 140) verbunden ist, und

g) jede Einheit (z.B. 20; 120) einen Aufbau (24; 120) umfaßt, der in dem Sinn flexibel ist, daß er eine Relativverschiebung der Glieder (10, 12; 110, 112) in zwei andere Richtungen (A, B) erlaubt, die jeweils senkrecht zu der einen Richtung (C) sind.

2. Vorrichtung nach Anspruch 1, wobei der Aufbau (24), der in dem Sinn flexibel ist, daß er eine Relativverschiebung der Glieder (10, 12; 110, 112) in die zwei anderen Richtungen (A, B; A, B) erlaubt, Schwenkmittel (25) umfaßt, die zwischen der starren Struktur (21) und wenigstens einem der Glieder (10, 12) angeordnet sind.

3. Vorrichtung nach Anspruch 1, wobei jede Einheit (z.B. 20) einen Arm (21) umfaßt, der an einem Ende an einem der Glieder (12) befestigt ist, ein Paar parallele Verbinder (24), die zwischen dem anderen Ende des Armes (21) und dem anderen der Glieder (10) verbunden sind, wobei der Arm (21) torsionsstarr um die Achse (A1) der Einheit (20) ist, ein erstes Schwenkmittel (22), das eine Winkelbewegung des Armes (21) relativ zu dem einen Glied (12) um eine Schwenkachse (23) senkrecht zur Achse (A1) der Einheit (20) erlaubt, wobei die Verbinder (24) in einer Richtung (C) senkrecht sowohl zur Richtung (A) der Achse (A1) der Einheit (20) als auch zur Richtung (B) der Schwenkachse hinausragen, die Verbinder (24) in der Richtung (B) der Schwenkachse (23) beab-

standet sind, und zweite Schwenkmittel (25), die eine universale Winkelbewegung jedes Verbinders (24) relativ zum anderen Glied (10) und relativ zum Arm (21) erlauben.

4. Vorrichtung nach Anspruch 1, wobei jede Einheit (120, 130, 140) einen torsionsstarren, aber anderweitig flexiblen Balg umfaßt, der zwischen den beweglichen und festen Gliedern (110, 112) befestigt ist.

5. Vorrichtung nach Anspruch 1 mit einem Vorspannmittel (162), das geeignet ist, die Glieder (10, 12) relativ zueinander in eine Rastposition vorzuspannen.

6. Vorrichtung nach Anspruch 1, wobei eines der Glieder (120) ein Gehäuse (149) umfaßt, das andere Glied (110) innerhalb des Gehäuses (149) liegt, und eine Flüssigkeit (162) innerhalb des Gehäuses (149) vorgesehen ist, um das andere Glied (110) kraft des Auftriebs der Flüssigkeit zu stützen.

7. Vorrichtung nach Anspruch 4, wobei eines der Glieder (112) ein Gehäuse (149) umfaßt, das andere der Glieder (110) innerhalb des Gehäuses (149) liegt, der Griffel (151, 152) vom Inneren des Gehäuses (149) her durch einen Teil vorsteht, der darin eine Öffnung (160) bestimmt, und wobei einer der Bälge (130) in einer Position zwischen dem anderen Glied (110) und dem Teil verbunden ist, und so, daß er den Griffel (151, 152) insoweit umgibt, als der letztere sich innerhalb des Gehäuses (149) erstreckt.

Revendications

1. Appareil pour détecter la position d'un objet (54; 154), comprenant:

a) un premier élément (10; 110) pour maintenir une pointe (52; 152) pour s'engager avec l'objet (54; 154),

b) un deuxième élément (12; 112) définissant un support pour la pointe,

c) trois unités (20, 30, 40; 120, 130, 140) montées entre les éléments respectifs (10, 12; 110, 112),

d) les unités (20, 30, 40; 120, 130, 140) possédant des axes respectifs mutuellement perpendiculaires (A1, B1, C1),

e) chaque unité (20; 120 par exemple) comprenant une structure (21; 120) qui est rigide en torsion autour de l'axe (A1) de l'unite', et une structure (22; 120) qui est flexible dans le sens permettant la translation relative des éléments (10, 12; 110, 112) dans une première direction (C) transversale à l'axe (A1) de l'unite' (20; 120), caractérisé en ce que

f) chaque unité (20; 120 par exemple) est reliée aux deux éléments (10, 12; 110; 112) indépendamment des autres unités (30, 40; 130, 140), et

g) chaque unité (20; 120 par exemple) comprend une structure (24; 120) qui est flexible dans le sens permettant la translation relative des éléments (10, 12; 110, 112) dans deux autres directions (A, B) respectivement perpendiculaires à la première direction (C).

2. Appareil selon la revendication 1, dans lequel la structure (24), qui est flexible dans le sens permettant la translation relative des éléments (10, 12; 110, 112) dans les deux autres directions (A, B; A, B) comprend un moyen de pivotement (25) disposé entre la structure rigide (21) et au moins un des éléments (10, 12).

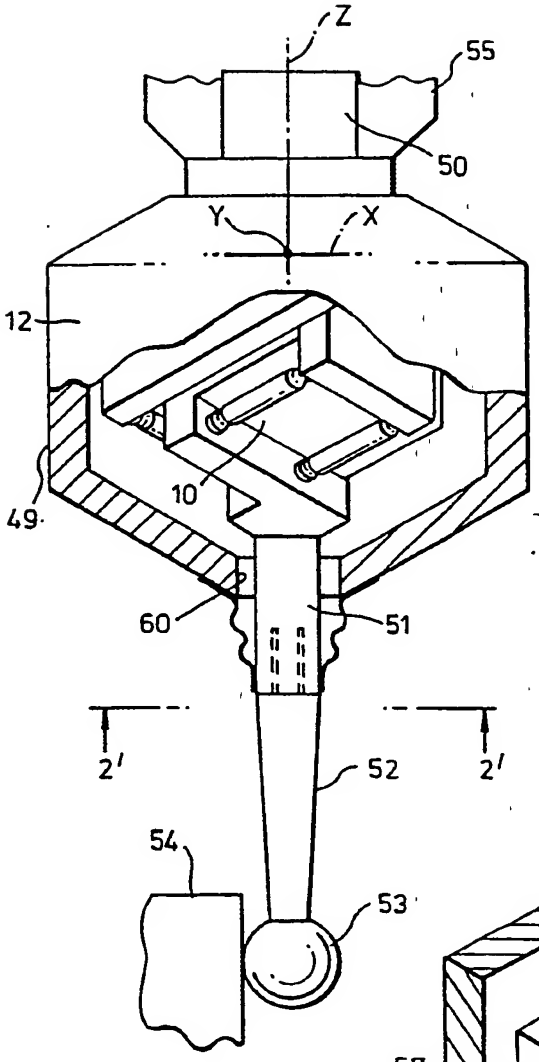
3. Appareil selon la revendication 1, dans lequel chaque unité (20 par exemple) comprend un bras (21) fixé à une extrémité à un premier des éléments (12), une paire de bielles parallèles (24) reliant l'autre extrémité du bras (21) à l'autre élément (10), le bras (21) étant rigide en torsion autour de l'axe (A1) de l'unité (20), un premier moyen de pivotement (22) permettant le mouvement angulaire du bras (21) par rapport au premier élément (12) autour d'un axe de pivotement (23) perpendiculaire à l'axe (A1) de l'unité (20), les bielles (24) s'étendant dans une direction (C) perpendiculaire à la fois à la direction (A) de l'axe (A1) de l'unité (20) et à la direction (B) de cet axe de pivotement, et les bielles (24); étant distantes l'une de l'autre, dans la direction (B) de l'axe de pivotement (23), et un deuxième moyen de pivotement (25) permettant le mouvement angulaire universel de chaque bielle (24) par rapport à l'autre élément (10) et par rapport au bras (21).

4. Appareil selon la revendication 1, dans lequel chaque unité (120, 130, 140) comprend un soufflet, rigide en torsion mais flexible autrement, reliant l'élément mobile à l'élément fixe (110, 112).

5. Appareil selon la revendication 1, comprenant un moyen de contrainte élastique (162) conçu pour contraindre élastiquement les éléments (10, 12) à une position de repos, l'un par rapport à l'autre.

6. Appareil selon la revendication 1, dans lequel un des éléments (120) comprend un logement (149), l'autre élément (110) est disposé dans le logement (149), et un liquide (162) est prévu dans le logement (149), afin de supporter l'autre élément (110) par la poussée d'Archimède du liquide.

7. Appareil selon la revendication 4, dans lequel un des éléments (112) comprend un logement (149), l'autre élément (110) est disposé dans le logement (149), la pointe (151, 152) s'étend vers l'extérieur, depuis l'intérieur du logement (149), en traversant une partie du logement qui définit une ouverture (160) dans le logement, et un des soufflets (130) est relié à une position entre l'autre élément (110) et la partie en question, et de manière à entourer la partie de la pointe (151, 152) qui s'étend à l'intérieur du logement (149).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55
50
Y
X
12
10
49
60
51
2'
2'
52
54
53

Fig. 1.

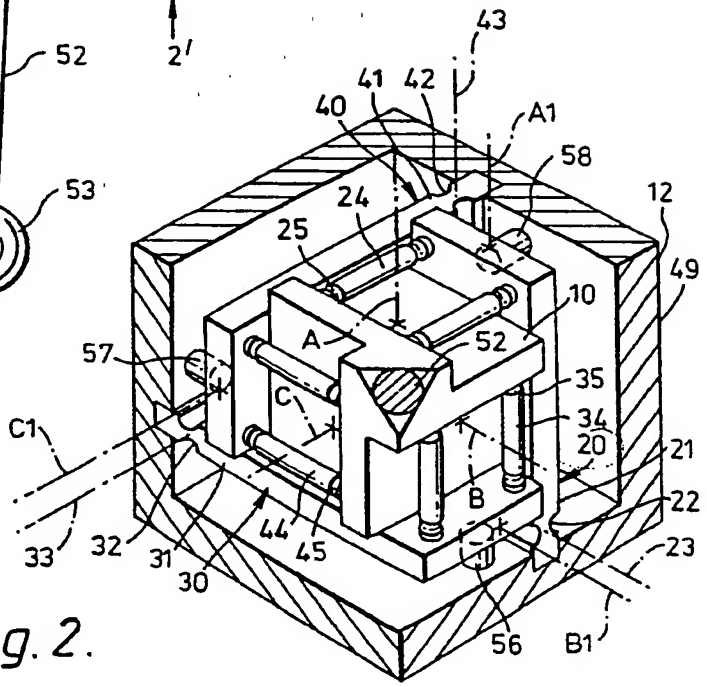
43
41
42
40
A1
58
12
24
25
49
10
A
52
57
35
C
34
C1
20
21
B
22
33
32
31
44
45
30
23
56
B1

Fig. 2.

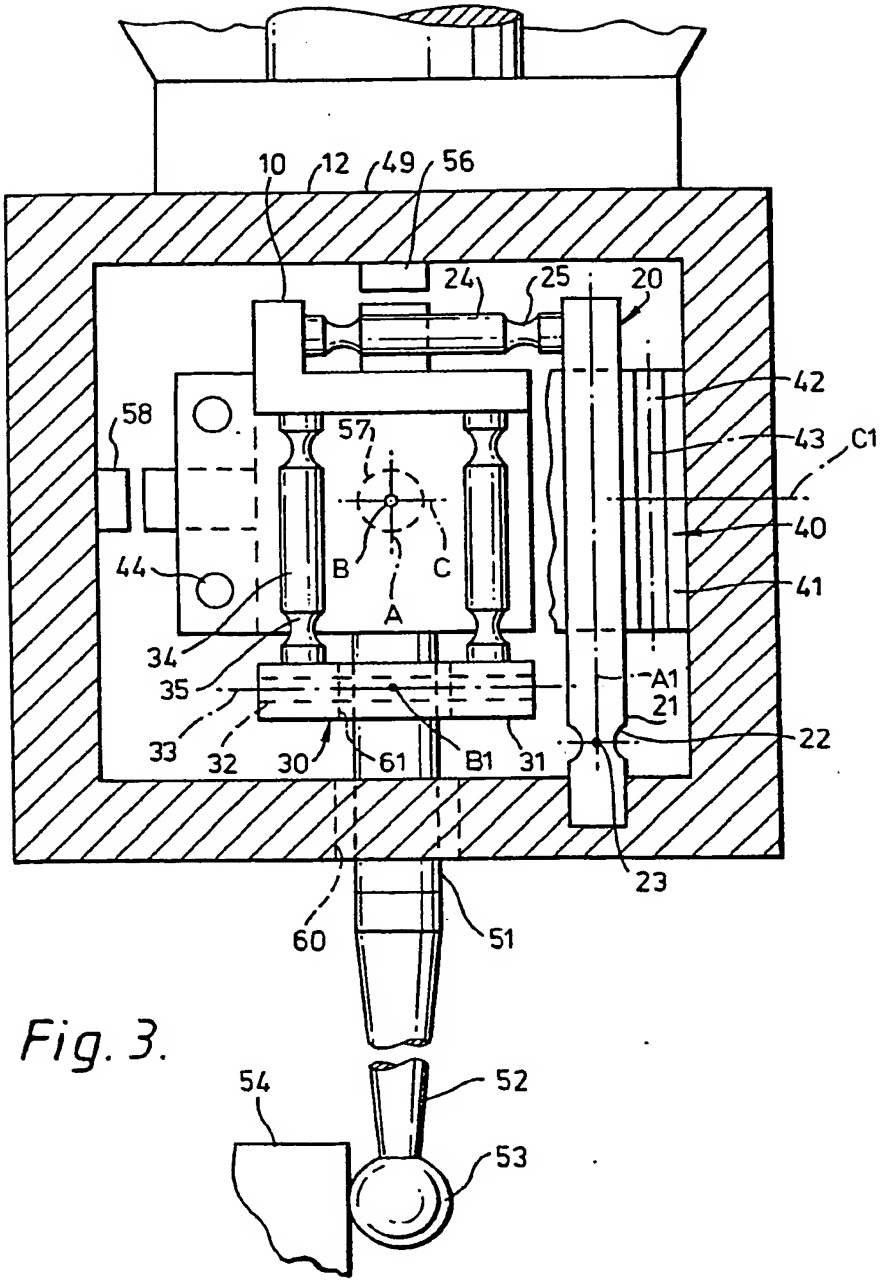
10
12
49
56
24
25
20
42
58
57
43
C1
40
44
B
C
A
41
34
35
A1
21
33
32
30
61
B1
31
22
23
60
51
54
52
53

Fig. 3.

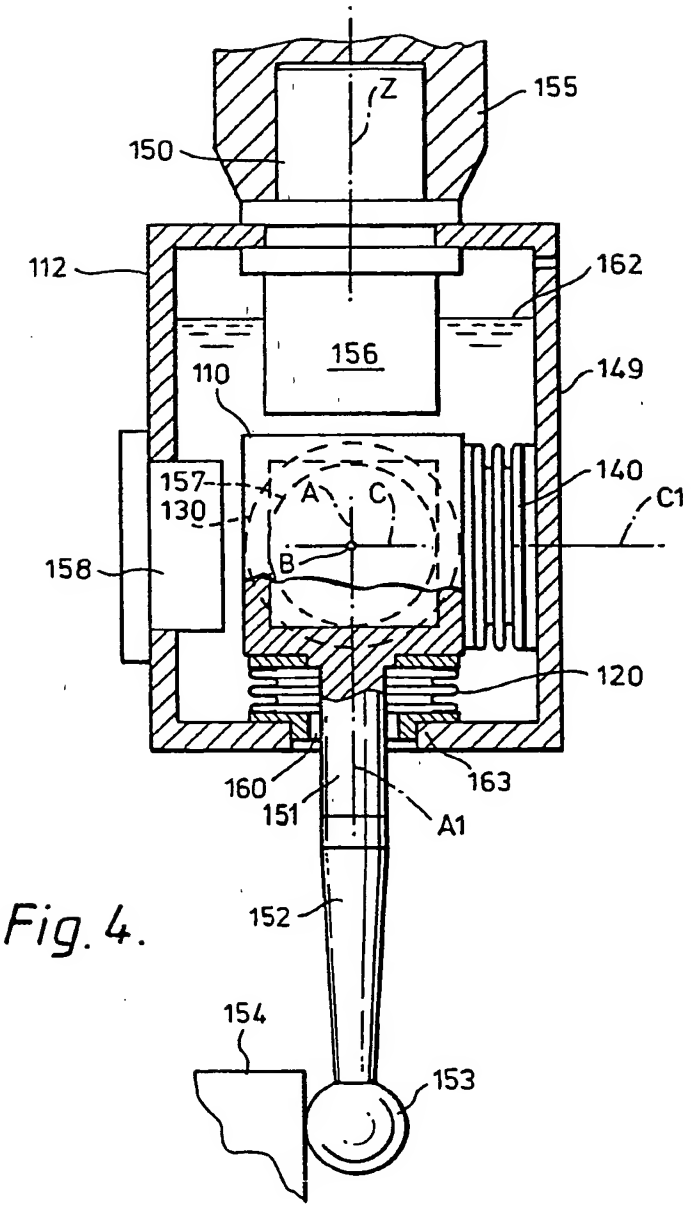
Z
155
150
112
162
156
110
149
140
157
130
A
C
C1
B
158
120
160
151
163
A1
152
154
153

Fig. 4.